Actinic EUV Mask Metrology

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There is urgent need for stand-alone actinic tools for the EUV mask infrastructure. Within the sequence of tools like Reflectometry, blank inspection, mask defect review, and pattern inspection affordable commercial availability is demanded for being in phase with EUV pilot lines by 2011.

For the most fundamental mask blank metrology of reflectivity and absorber homogeneity, AIXUV's mask blank reflectometer is well on track to HVM considering learning by in-house and blank supplier use. Reflectometry is additionally required in the mask's life cycle through mask-house, point of use and cleaning validation for which we suggest solutions.

Actinic mask blank defect inspection is considered crucial and is required at mask blank suppliers and perhaps in mask houses. This gives a very narrow "product window" in sense of the combination of tool costs and market size, demanding an effective path for the development to be triggered by community in combined effort. We have set-up a proof of concept experiment based on an EUV microscope on which first results are presented together with tool extrapolation. Provided the expected results, a consortium of partners which realizes a fast development plan has been defined. Target numbers of such a tool is <2.5 M€, sensitivity to sub-30 nm defects and <2 hours for full inspection.

Actinic tools like EUV-AIMS or actinic EUV mask inspection might benefit in costs and throughput from a high brilliance EUV Source Concept which we suggest.

2 TOS RWTH RHEINISCH-WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN LEHRSTUHL FÜR TECHNOLOGIE OPTISCHER SYSTEME

3 Fraunhofer ILT Institut Lasertechnik

1 AIXUV EUV-Technology

Polychromatic EUV Mask Blank Reflectometer (MBR)

Top/Level Specs

Reflectance 0.01% - > 70%
Dynamic Precision < 0.2 % PV
Static Precision < 0.1 % PV

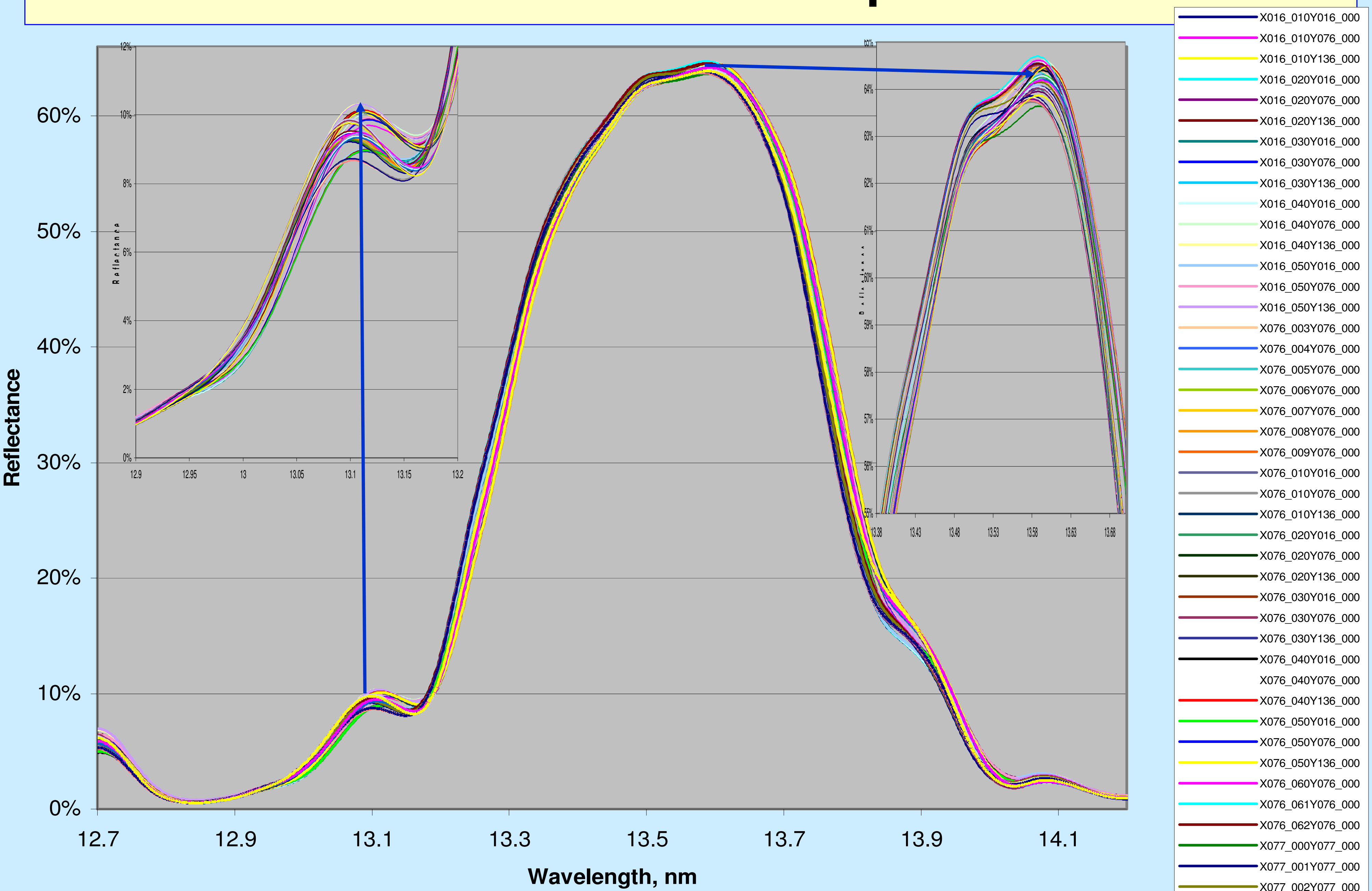
Wavelength Range: 12-15 nm
WL Accuracy < 0.5 pm

CWL_50 13 – 14 nm
Dynamic Precision: < 3 pm PV

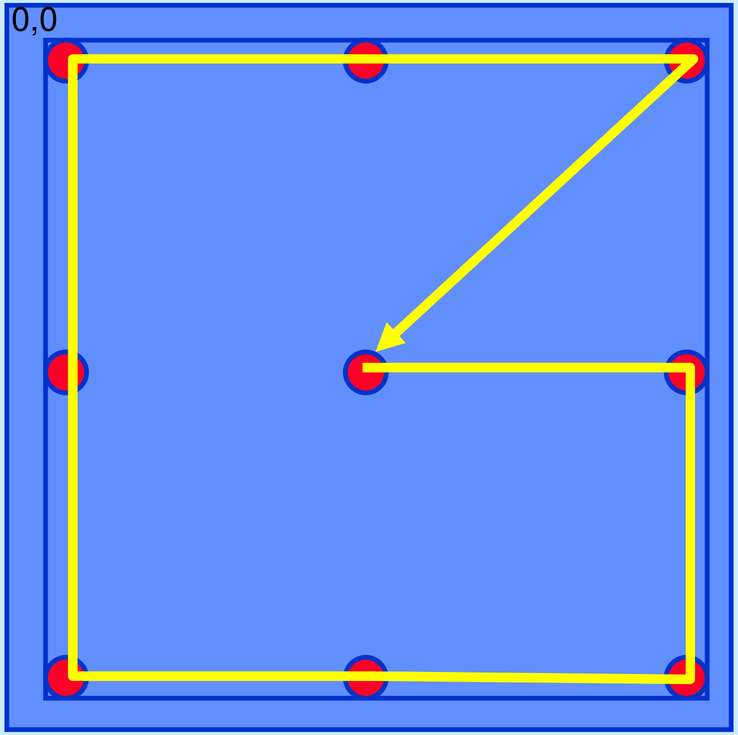
FWHM : 50 pm/ 1.50 nm
Dynamic precision: < 3 pm PV

Dedicated for SEMI compatible qualification of EUV mask-blanks

Reflection Curves of Round Trip measurements

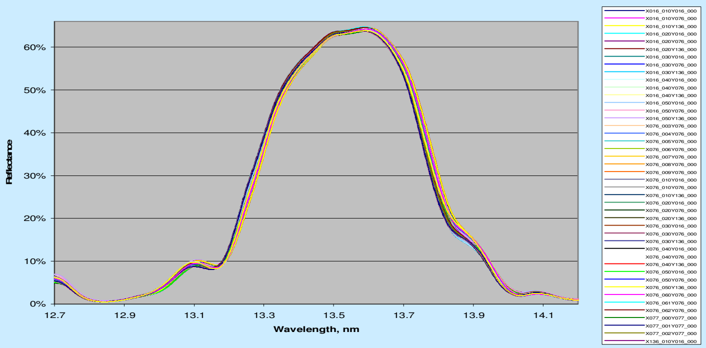


Dynamic Reproducibility in 9 spot Round-Trip measurements



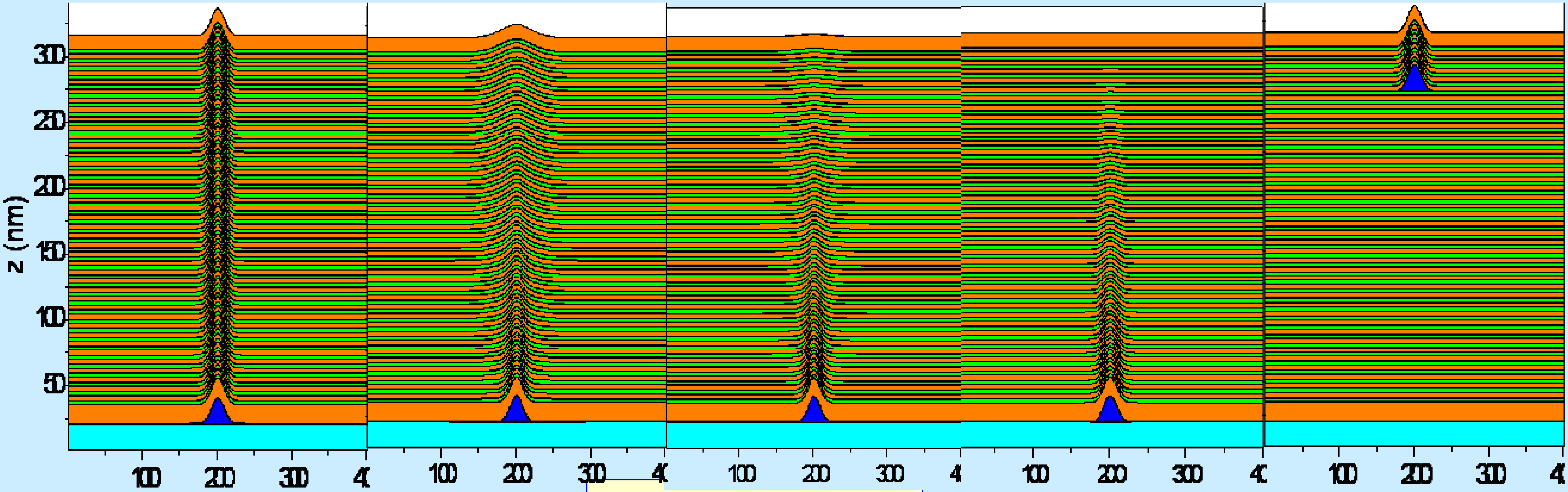
		16			76			136		
		Peak R	CWL_50	FWHM	Peak R	CWL_50	FWHM	Peak R	CWL_50	FWHM
16	Avg.	63.96%	13.527	0.502	64.43%	13.540	0.506	64.22%	13.536	0.504
	P-V	0.14%	1.0	0.3	0.20%	0.7	1.2	0.22%	0.6	1.0
76	Avg.	64.25%	13.534	0.503	64.46%	13.525	0.505	64.43%	13.543	0.505
	P-V	0.15%	1.0	0.3	0.31%	0.7	1.2	0.06%	0.6	1.0
136	Avg.	63.72%	13.522	0.500	64.16%	13.537	0.503	63.91%	13.532	0.501
	P-V	0.14%	0.9	0.8	0.10%	0.7	0.6	0.20%	0.7	0.6

Round Trip path was measured 5 times plus 50 times center measurement. (Duration of total measurement: < 2 hours

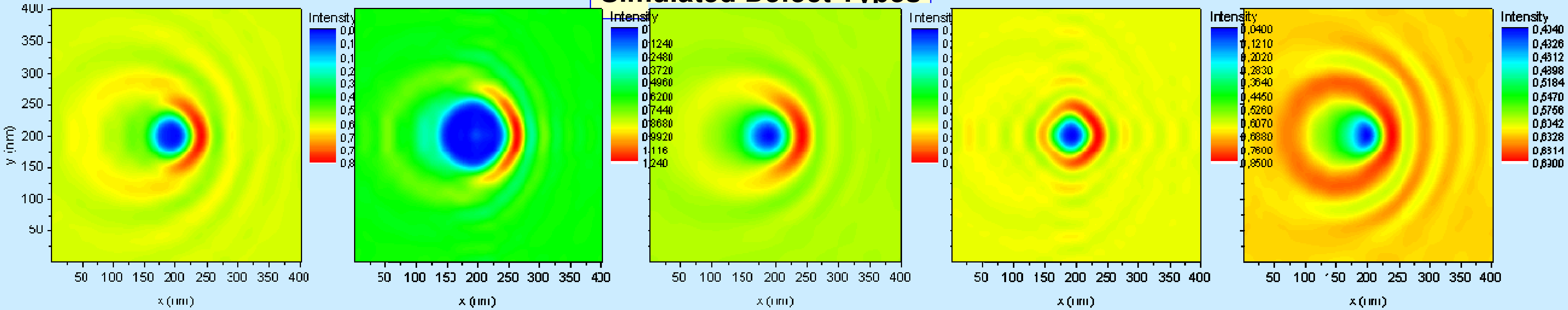


	Peak R	CWL_50	FWHM	
Average Spot Av.	64.17%	13.533	0.503	nm
Max	64.46%	13.543	0.506	nm
Min	63.72%	13.522	0.500	nm
Sampe Variation P-V	0.45%	11.13	3.56	pm
Average Tool P-V	0.17%	0.77	0.78	pm
Sample / Tool	2.67	14.52	4.57	
Sample Target 2010, 3σ	0.47%	5.00	5.00	
Target/Precission	5.6	13.0	12.9	

Simulation of Defect Detection



Simulated Defect Types

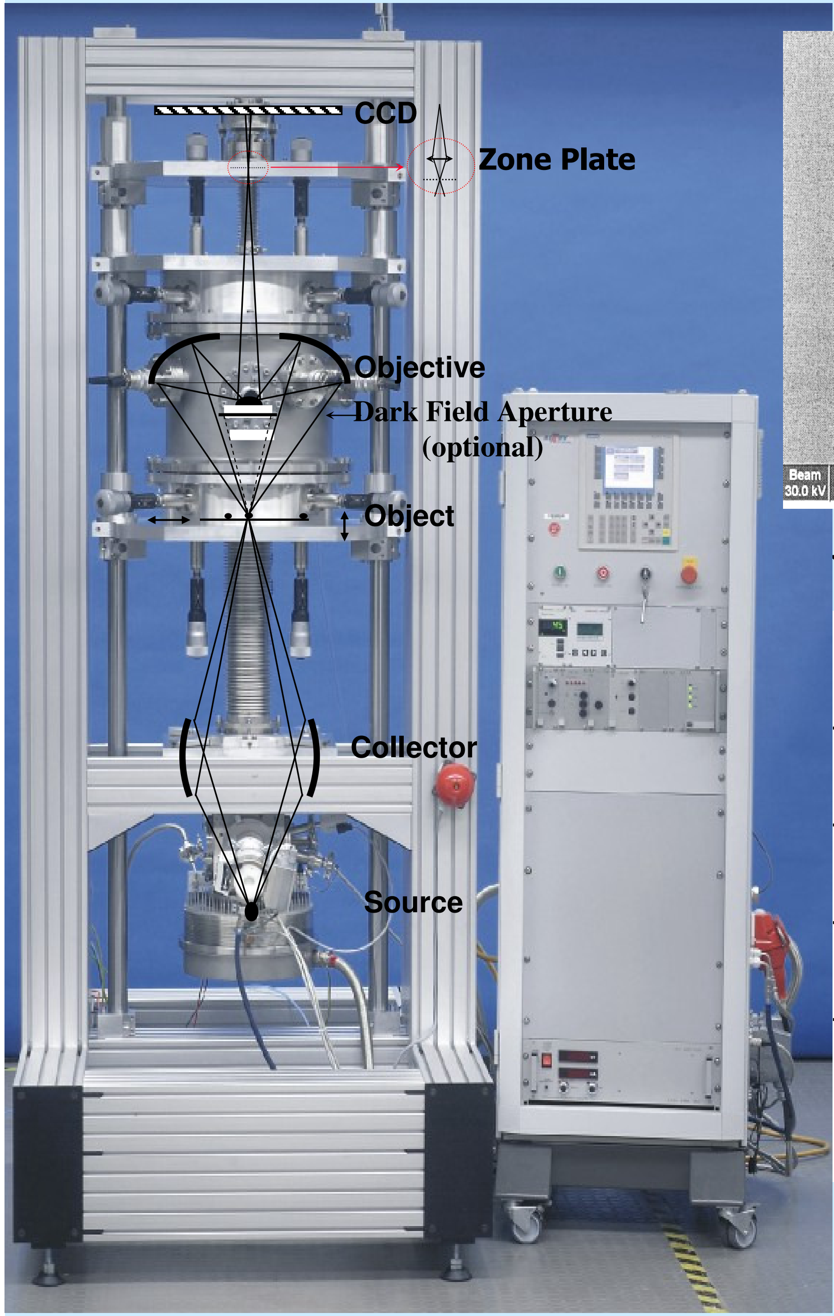


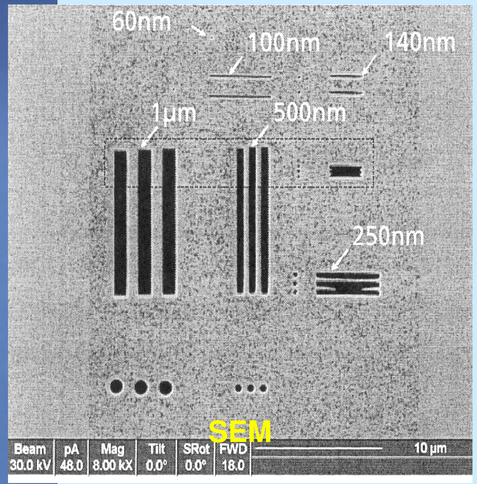
Simulated Surface Electrical Field

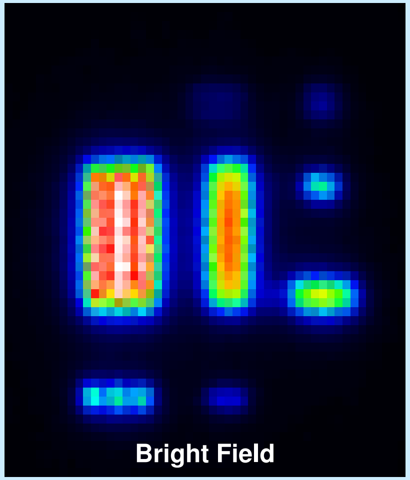
All Types of Defect by distortion cores exhibit amplitude variation and diffraction of electrical field

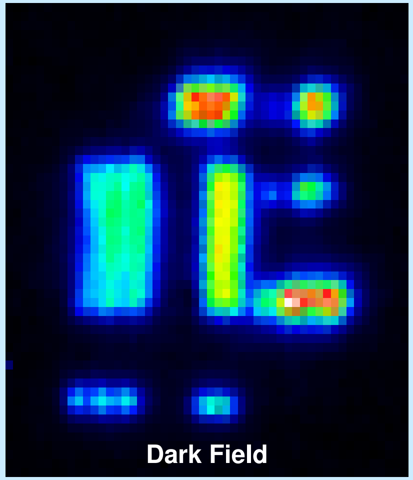
For further details see poster 'Simulation of defect scattering efficiency …. ' by A. Maryasov

Transmission ‘Defects’ Studies in EUV/Microscope 20x

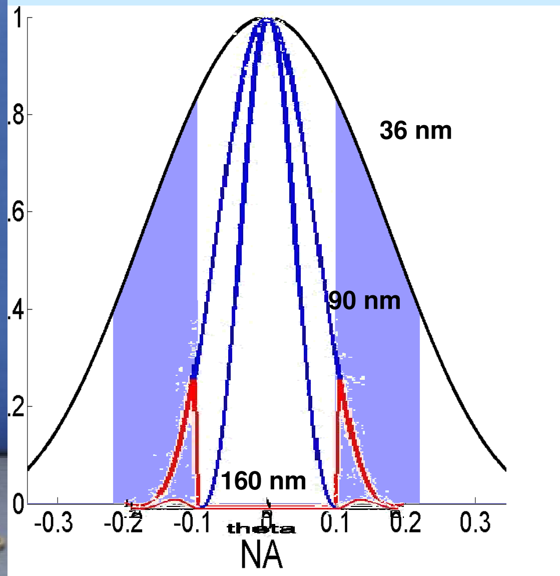


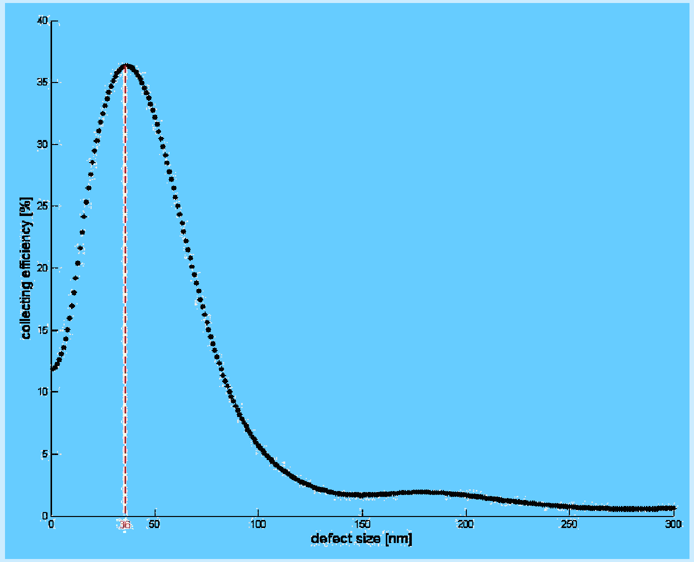






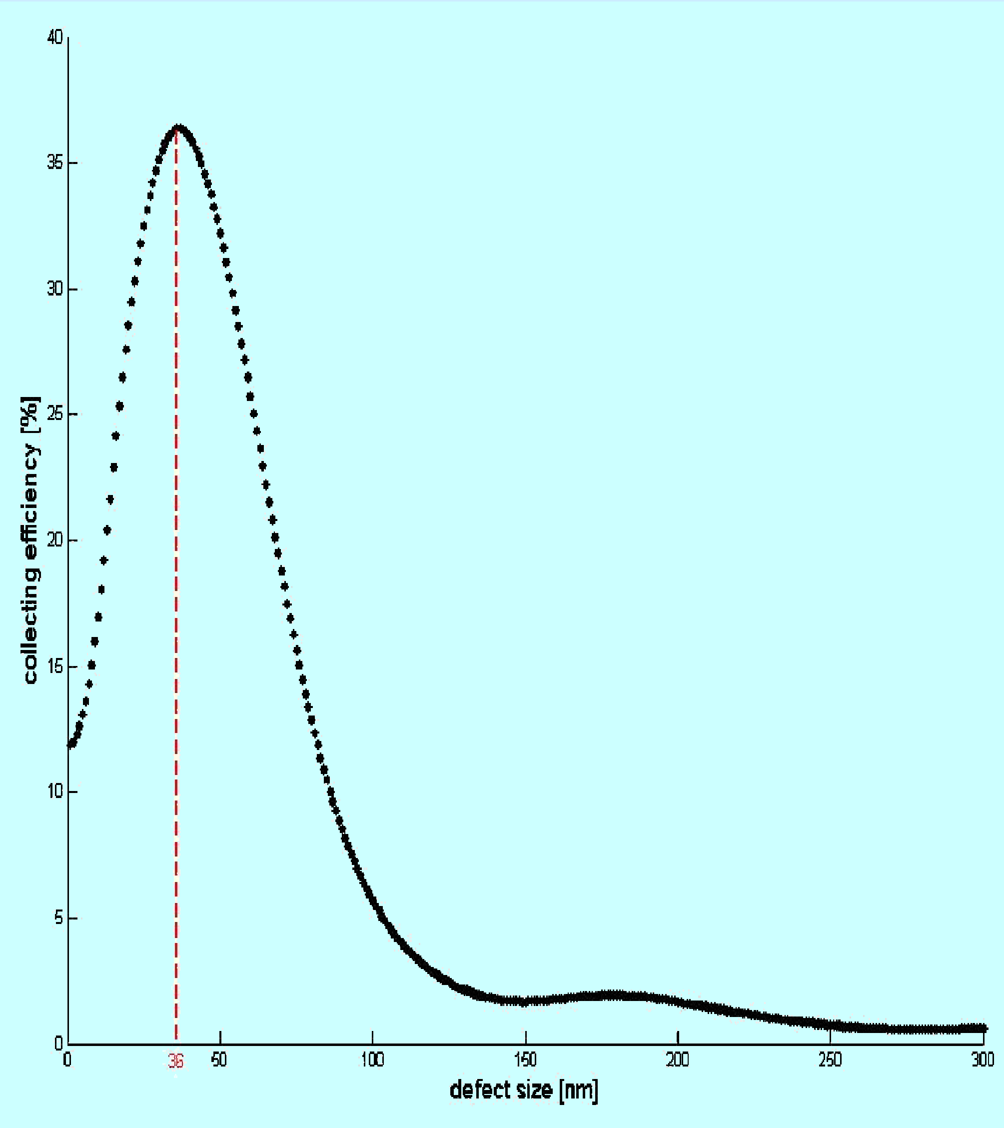
mall structures below 150 nm exhibit sufficiently higher contrast in EUV dark field images



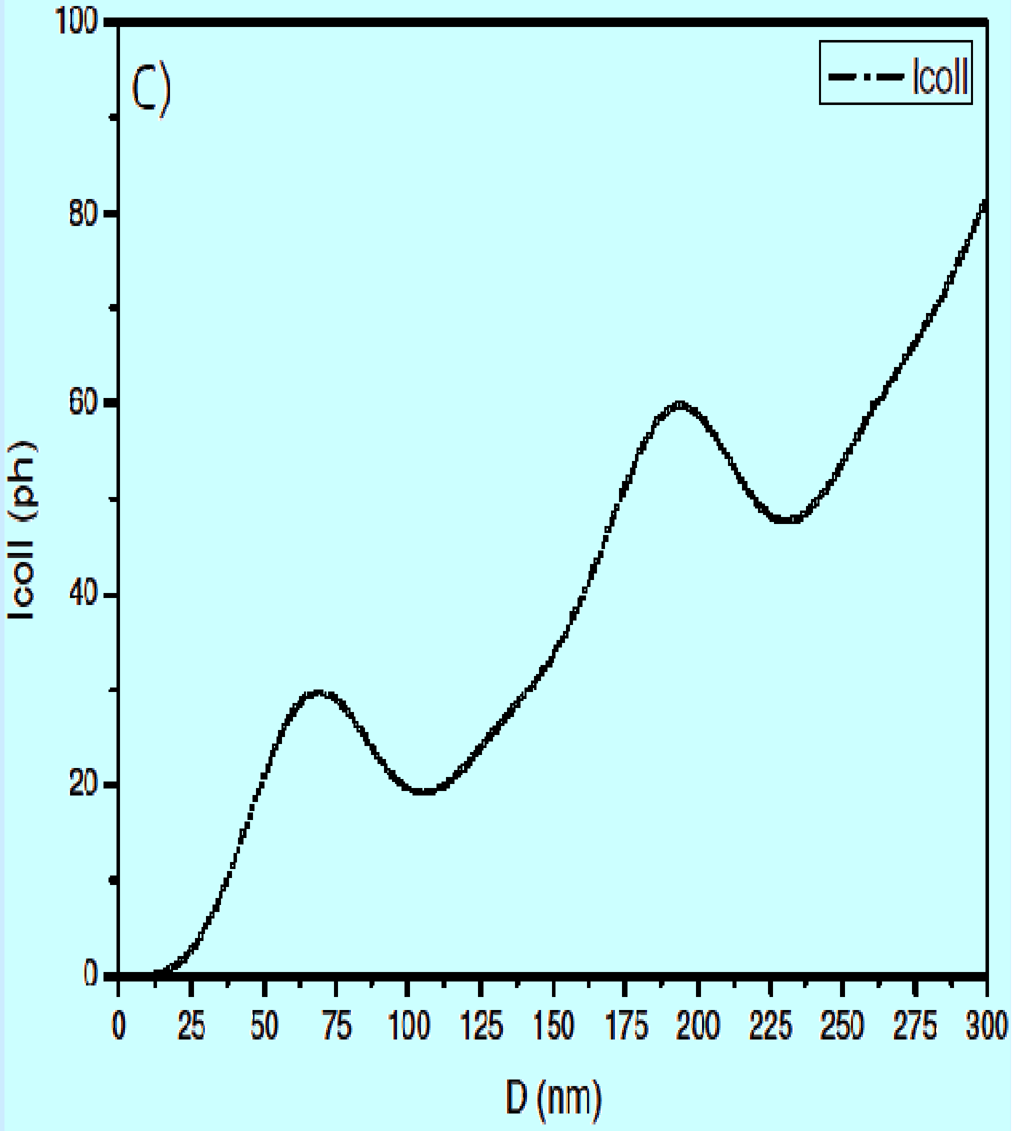


Amplitude Variation is diffracted into far field; High
Collection efficiency for small defects, low for larger structures

Defect Collection Simulation



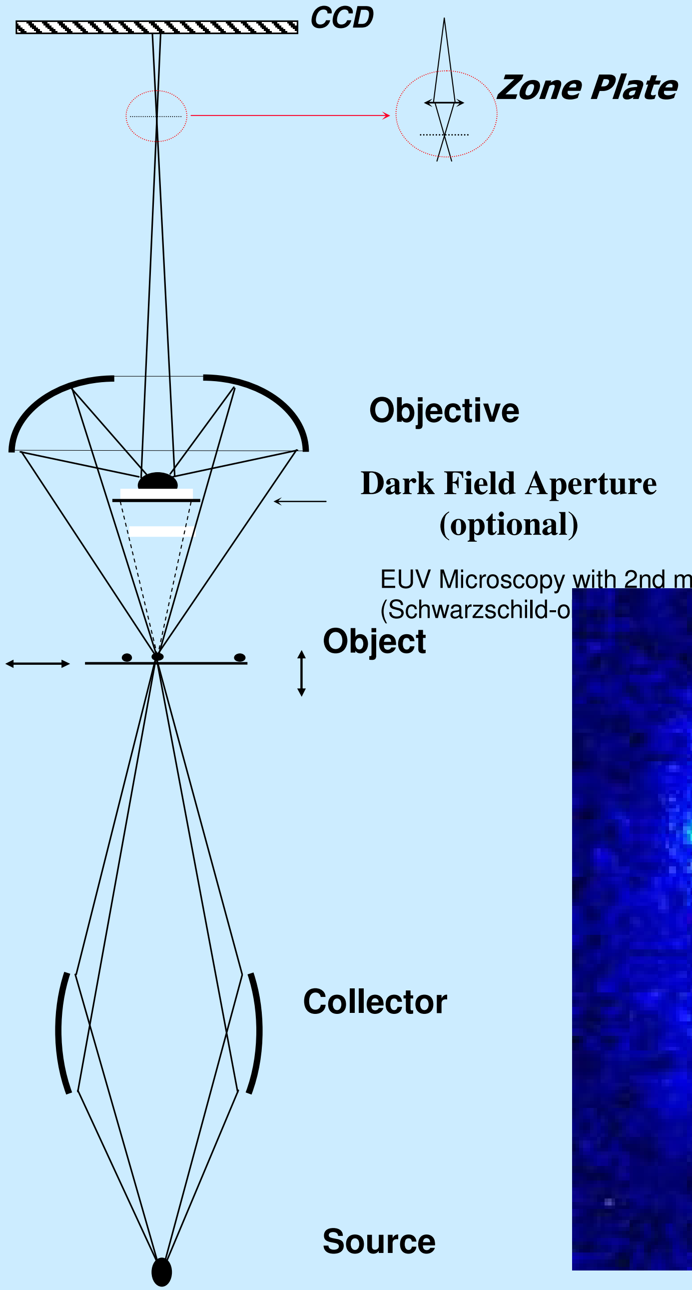
Fraunhofer far field estimation on scatter efficiency as function of defect size

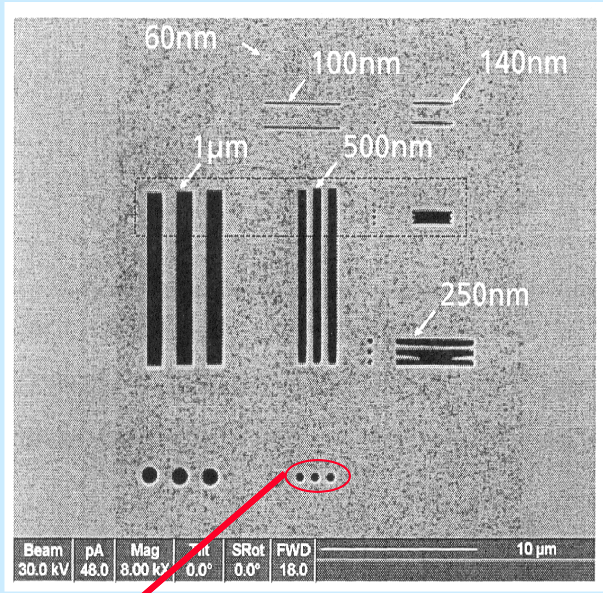


Estimated number of photons collected by CCD from 0.5 J/cm² on sample

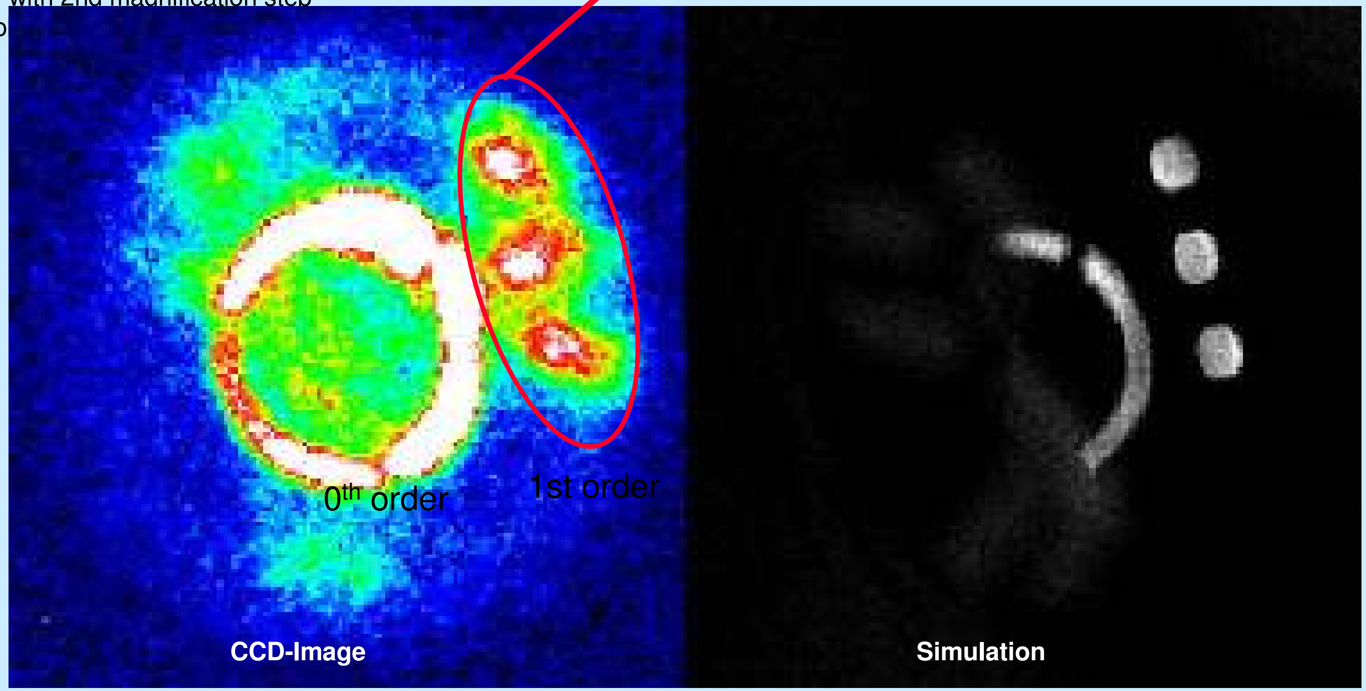
> 10 photons from 18 nm defect requires about 0.1 J/mm²

2nd Magnification of dark field imaging



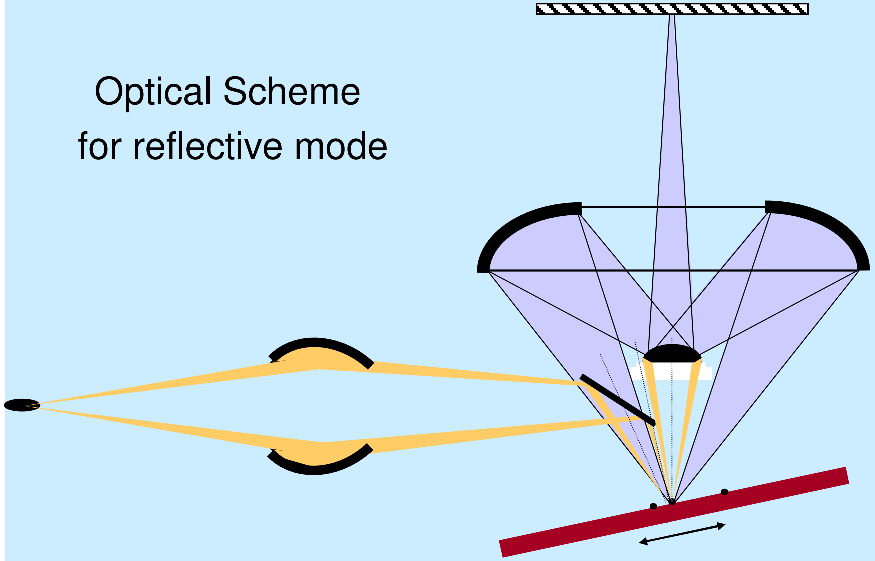


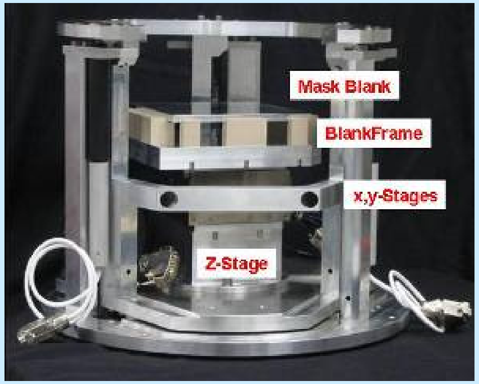
EUV Microscopy with 2nd magnification step
(Schwarzschild-o



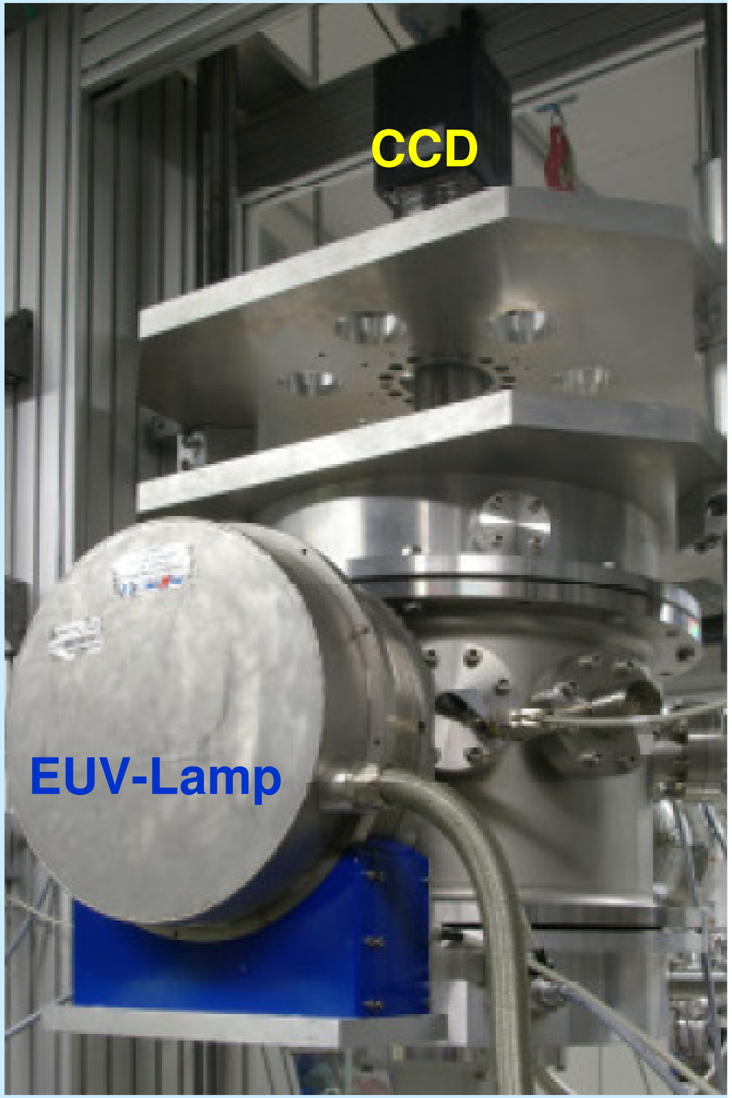
Transfer to Reflection Mode and First Images

Optical Scheme
for reflective mode





Microscope modified to measure full mask blanks



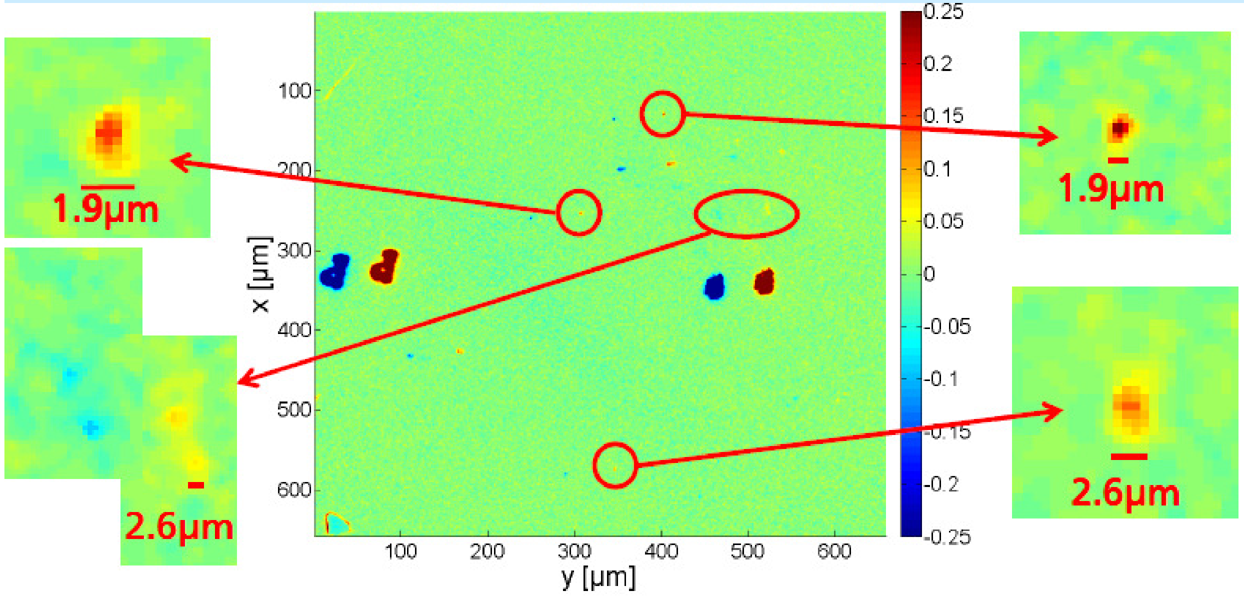
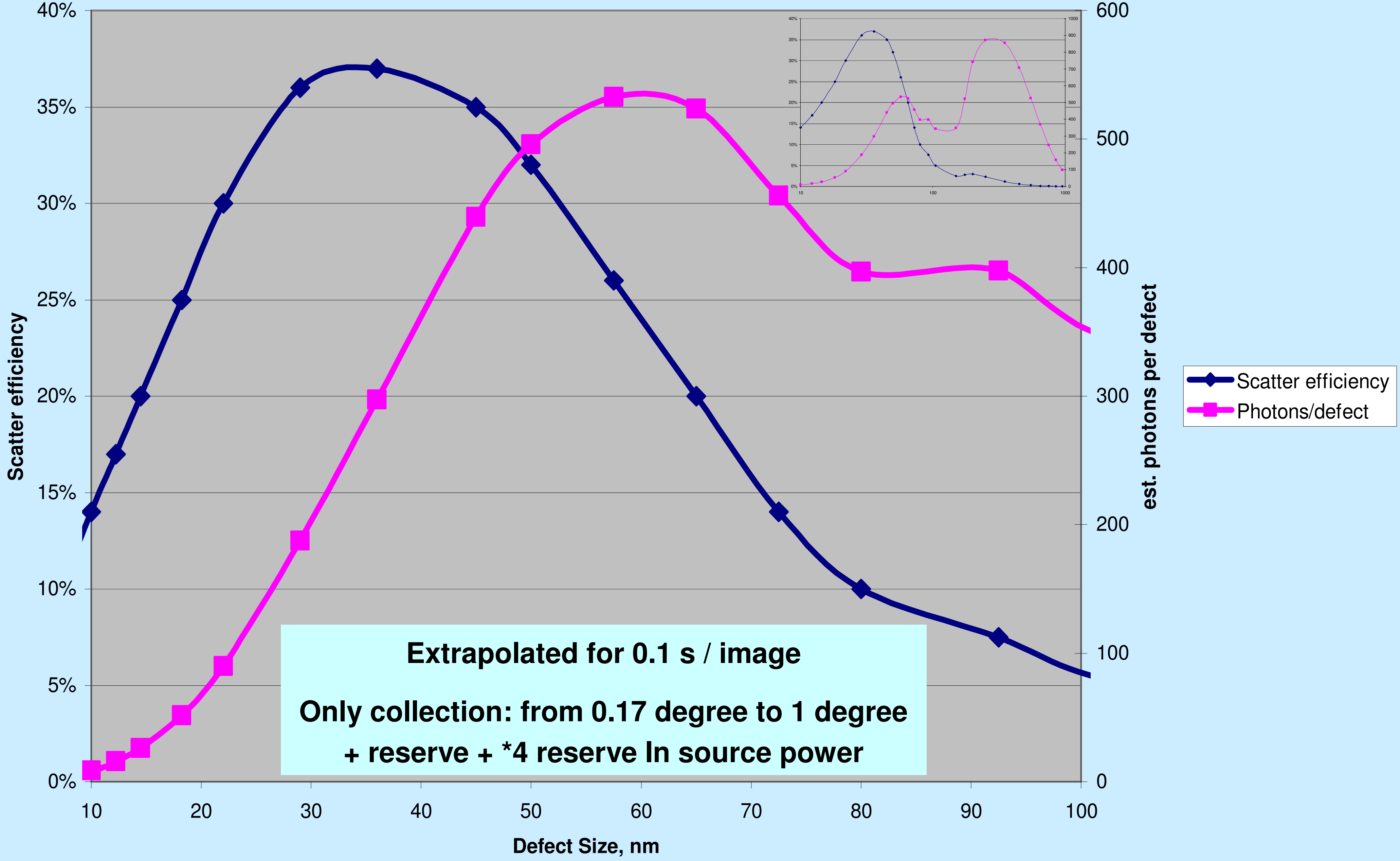


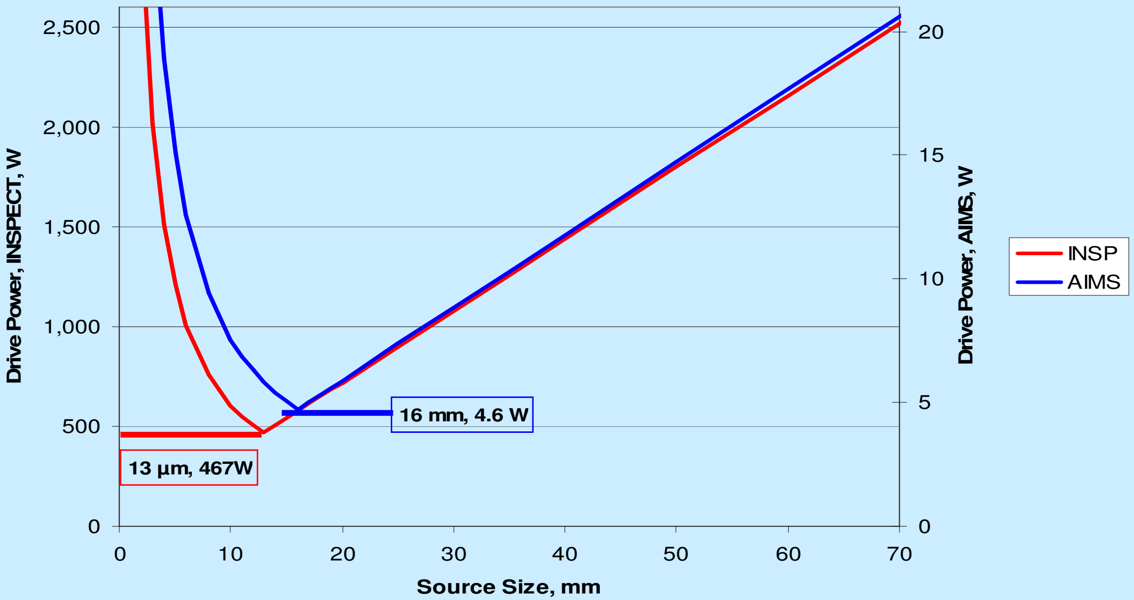
Image of multilayer mirror native defects
(shifted measurement substracted, hence each defect is in red and blue laterally shifted)

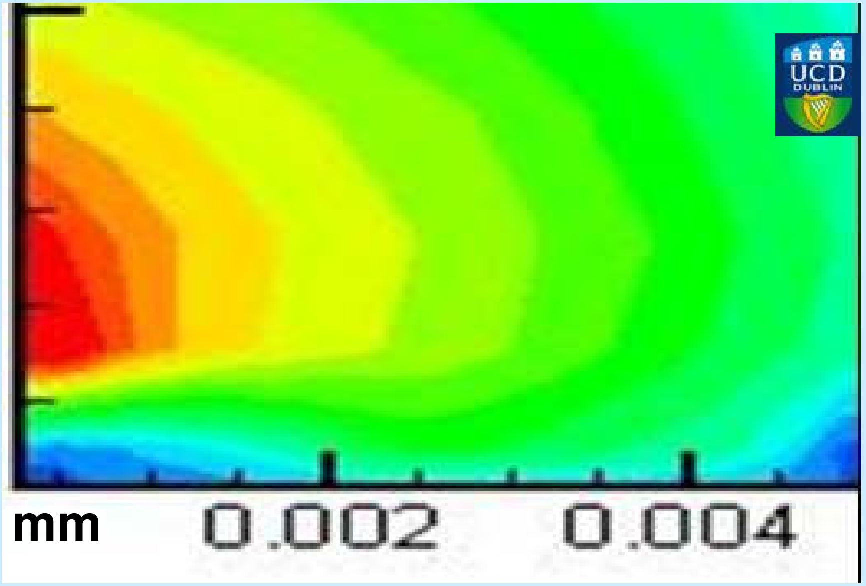
For further details see poster 'Experiments on defect inspection ….' by S. Herbert, et. al

Defect Detection Status (est. dose = 0.5 photons / nm^2)



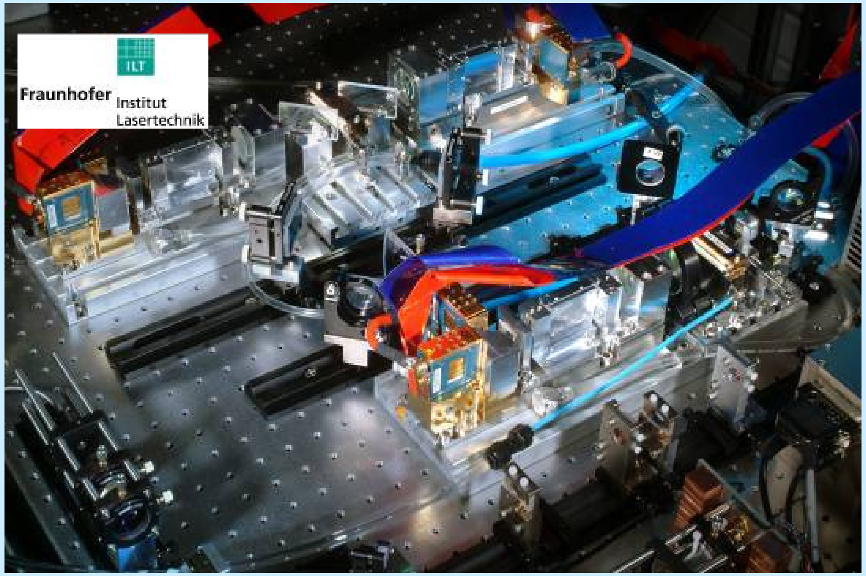
High Brightness EUV-Source





If small source size would be available,
Acceptable laser drive powers would be sufficient
for supporting AIMS and APIT

Simulation of EUV-emission of LPP with dedicated laser parameters shows feasibility of < 10 µm Source



Laser system for high brightness soft x-ray source is available with 200 W average power

Straight forward solution

1.) Downgrade Laser in Pulse energy (no amplifiers)

2.) Increase Rep/rate (means of Power Scaling)

3.) Test >100 kHz Target Concept

4.) Solve stability issue

5.) Perform Product development (Laser commercialization path is available)

Summary & Outlook

EUV Reflectometry is ready for HVM up-ramp roadmap:
Precision and accuracy of reflectometer is in roadmap spec and has the potential to follow the future demands of tighter requirements.

Roadmap is set for the development of stand alone actinic EUV mask blank inspection tool.

Proof of principle has successfully been accomplished with Research Test bench.

Throughput scaling data to be obtained from implementing collector;
Significant shorter exposure times expected.

Full process modeling is available. Assumptions from modeling have been confirmed.
Tool scaling to be confirmed

Tool Architecture Components and solution path is known.

Next step is qualification of sensitivity and throughput model with programmed defects and commercial realization path.

Concept and development plan for straight forward high brightness EUV Source available.
Work to be started.

Please see our posters and our partner's ones for further details on this topics

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